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PUBLICATIONS OF THE LICK OBSERVATORY,  
VOLUME VI.

Volume VI of the *Publications of the Lick Observatory* is a substantial book of 405 pages, containing the work of Professor RICHARD H. TUCKER with the Repsold meridian-circle from August, 1896, to March, 1901. Four thousand five hundred stars have been observed, 11,700 complete observations of both Right Ascension and Declination having been made, and 2,700 other determinations of one of these coordinates only. That so large an amount of high-class work has been done by a single observer in a time so short is exceedingly creditable to the Lick Observatory and to the astronomer who made the observations.

There are six main divisions of the volume, and we shall review each separately.

THE DECLINATIONS OF THE BETHLEHEM LATITUDE STARS.

The most extensive series of observations for the determination of variation of latitude ever made in this country is that executed by Professor C. L. DOOLITTLE at South Bethlehem, Pa. It is evidently a matter of importance that the declinations of Professor DOOLITTLE's stars should be known with considerable accuracy, and should be reduced to some standard system. Professor TUCKER's observations have been planned with a view of accomplishing this reduction by means of observations of the stars in conjunction with suitable fundamental stars.

The average number of fundamental stars observed each night was more than one fourth of the total number observed on that evening. The working list of stars used in the South Bethlehem observations originally contained 347 stars, and three were added afterwards; two of these were not observed. The general plan was to observe each star four times, the instrument being reversed for the second pair of observations. It was Professor DOOLITTLE's original intention to use the system of BOSS for all the stars. Professor TUCKER has reduced every star to this system, and has compared with the system of AUWERS.

There were 68 stars common to Boss's "Declination of Fixed Stars," and the *Berliner Jahrbuch*. By comparing the

declinations of these Professor TUCKER has derived the following formula:—

$$\text{Boss-B. J.} = -0''.10 + 0''.002 \delta^\circ$$

A comparison of the two systems was also effected in another way. For each of 120 stars the Declination was observed. The result thus obtained was compared with that given by Boss, and also with that of the *Berliner Jahrbuch*. Thus resulted the following formula:—

$$\text{Boss-B. J.} = -0''.08 + 0''.001 \delta^\circ$$

The agreement of these two formulas is striking, and shows the accuracy of the observations. It also appeared from this investigation that the probable error of a *B. J.* declination is  $\pm 0''.24$ .

The conclusion reached as to the systematic errors of the observations is, that those due to flexure, bisection, and the difference U. C.—L. C. are practically negligible.

By discussing the probable error of an observed declination, the following results were reached:—

Probable-error observation,  $\pm 0''.09$ , mean of four.

Probable-error graduation,  $\pm 0''.08$ , two positions.

Probable-error fundamentals,  $\pm 0''.08$ , group of twelve.

Total probable error,  $\pm 0''.15$ .

These figures speak eloquently of the accuracy of the work.

From each observation of a fundamental star combined with the nadir-reading (taken three times each full night) a value of the latitude was obtained. After applying the corrections for variation of latitude computed from CHANDLER's elements, and combining the observations by pairs in such a way as to eliminate the division error of the nadir-reading, the following value of the normal latitude was reached:—

$$\phi_0 = 37^\circ 20' 25''.42 (\pm 0''.03)$$

The star-places originally derived by Professor DOOLITTLE were taken directly from Boss, or reduced to that system, or occasionally adopted from some other authorities. Professor TUCKER finds that the probable error of one of these declinations is  $\pm 0''.4$ . It is evident that wisely directed and accurate observation with a modern meridian-circle has given results

superior to those obtained by a careful discussion of material previously obtainable.

ADDITIONAL STANDARD CLOSE CIRCUMPOLAR STARS.

These stars, twenty-one in number, all lie above  $82^\circ$  of North Declination, and half of them are above  $85^\circ$ . They were observed at the request of Dr. AUWERS. The mean places for each year of the interval 1895-1905 have been published in *A. N.* 3440. If ephemerides giving the apparent places of these stars could be issued from year to year, or to cover periods of five years, they would be very useful to all observers who have occasion to make determinations of azimuth. As their magnitudes range from  $5\frac{1}{4}$  to  $7\frac{1}{2}$ , they could be handled even with the comparatively small instruments used in the field.

Each star was observed sixteen times, eight times at each culmination, half the time with the fixed circle east, and half the time with the instrument reversed. The ten close circumpolars which already form a part of AUWER's A. G. C. system were employed in obtaining the constants of reduction; the clock-stars were chosen from a list selected by Dr. AUWERS; usually eight of the clock-stars were used each night.

Professor TUCKER gives a careful discussion of the possible errors affecting his observations, including those of the close circumpolars which were employed as fundamental; all of these quantities are fractions (generally small) of a second of arc. An important by-product of the investigation is, that the Pulkova refraction-tables do not accurately correspond to the meteorological conditions at Mt. Hamilton. The probable error of the final position of a star derived from sixteen observations is, in R. A.,  $\pm 0^s.005 \sec \delta$ , and in Decl.,  $\pm 0''.08$ . In this connection Professor TUCKER makes the following interesting statement: "As indicating how large a part the unavoidable errors in the reduction may play, the simultaneous observations of the transits of the two stars of the pair  $l_1$  and  $l_2$  of the list give an interesting illustration. Each star was observed completely, upon sixteen nights, and both transits are recorded. This gives thirty-two values of the mean difference at transit,  $7^s.56$ , with the probable error of one determination,  $\pm 0^s.087$ . The probable error of a transit is thus found to be  $\pm 0^s.061$ ,

which reduces to  $\pm 0^s.001$  sec  $\delta$ , for the mean of thirty-two observations."

Such accuracy plainly shows the excellent quality of the "seeing," as well as the skill of the observer.

#### ZODIACAL STARS.

In the summer of 1898 the positions of half a hundred zodiacal stars were obtained by request of Sir DAVID GILL, for use in his heliometer measures of the major planets. In the first seven months of 1900 these stars were reobserved, and about an equal number added. For the earlier observations the places of the thirteen fundamental stars were furnished by Dr. GILL. By means of eight of these fundamental stars a comparison of Dr. GILL's places with those of Dr. AUWERS was made. The mean difference in Right Ascension is  $0^s.011$ , and in Declination it is  $0''.35$ . In order to investigate the systematic error in Declination, Professor TUCKER compared the value of the latitude derived from the thirteen fundamental stars in Dr. GILL's list with the value obtained by observing circumpolars. The two results differ  $0''.56$ ; if only the eight stars given by AUWERS are used, and his declinations are adopted for them, this discrepancy is reduced to  $0''.27$ .

For the observations of 1900, fourteen fundamental stars were selected by Dr. GILL, but he published no places for them. The places of six of them were therefore taken from the *Berliner Jahrbuch*, and Dr. AUWERS's corrections were applied to them. The eight stars which were not found in the *Jahrbuch* were specially observed, using AUWERS's corrected *B. J.* stars as fundamental. Ten of the fourteen are found in NEWCOMB's Fundamental Catalogue. The average difference between the coordinates adopted by Professor TUCKER and those given by NEWCOMB is  $0^s.018$  in Right Ascension, and  $0''.01$  in Declination. The probable errors of the places finally deduced for the zodiacal stars are for the annual results:—

$$\begin{aligned} &\pm 0^s.011 \text{ in R. A.} \\ &\text{and } \pm 0''.17 \text{ in Decl.} \end{aligned}$$

Experiments with screens, to determine the correction to transits due to the magnitudes of the stars, gave the value of this as  $-0^s.006$  per magnitude, faint stars being recorded later.

## THE PIAZZI STARS.

All of the stars of Southern Declination found in PIAZZI'S Catalogue were given place in the working list, which thus embraced 3,088 stars. The observations were undertaken at the suggestion of Dr. H. S. DAVIS, who is engaged in a re-reduction of PIAZZI'S original observations. Two observations of each star were made, and several which were used as fundamental stars have naturally been observed a greater number of times. In all 7,600 observations (including circumpolars and nadirs) were made, on 146 nights. For 4,400 of the observations the circle-microscopes were read by Dr. R. T. CRAWFORD. When he assisted in this manner, the average number of observations per night was sixty-one; when Professor TUCKER was alone, the average number was forty-six.

The excellence of the meteorological conditions and of the construction of the observing-room is shown by the fact that ordinarily there is not a difference of one degree between the temperatures outside and inside the room when it is closed. Upon the best nights the temperature remains nearly constant, often changing less than a degree for several hours. The maximum change of barometric-reading during the four or five hours of an observing period was four hundredths of an inch. The care and skill of the observer are abundantly attested by the table of probable errors for those stars which were not fundamental. Since many of the observations were made at very low altitudes, where the images were poor, and the effects of irregular refraction much greater than the average, the observations were divided into five zones, each  $10^\circ$  in width. For stars between the equator and  $30^\circ$  south the probable error of the mean of two observations may be well represented by the expressions—

$$\begin{aligned} & \pm 0^s.016 \sec \delta \text{ for R. A.} \\ & \text{and } \pm 0''.23 \text{ for Decl.} \end{aligned}$$

From  $30^\circ$  downward to  $46^\circ.8$ , which is the extreme southern limit in Declination, the error in Right Ascension increases a trifle, but that in Declination increases quite rapidly. Professor TUCKER has derived the following approximate expression for the probable error in declination:—

$$\pm [0''.15 + 0''.09 (\tan Z. D. - 1)]^*$$

\* The reviewer has taken the liberty of inserting the [ ], which do not appear in the original.

At the southern limit this expression reaches the value  $\pm 1''.0$ , when the star is but  $6^\circ$  above the horizon.

The places used for the fundamental stars were determined by an extended discussion, for the details of which the reader must refer to the volume itself. The following direct quotations will give an idea of the problem by which Professor TUCKER was confronted and his solution of it:—

“With the use of the Poulkova Refractions we should obtain the Latitude  $37^\circ 20' 25''.39$  from the Circumpolar stars observed at both culminations, during this series. The observations of Latitude from the *B. J.* Southern stars would indicate a mean correction of  $-0''.16$  for its system of Declinations, down to  $-31^\circ$ . The Latitude observations of the list of 303 would indicate a correction of  $-0''.56$  for its Declination system down to  $-25^\circ$ . Employing NEWCOMB'S Declinations down to  $-31^\circ$ , the indicated correction would be  $-0''.68$ . Employing the Declinations of BOSS, for the Standard stars  $-20^\circ$  to  $-31^\circ$ , the correction to his system would be  $-0''.72$ . Similarly for AUWERS'S Southern Fundamental Catalogue,  $-20^\circ$  to  $-31^\circ$ , the correction would be  $-0''.92$ .

“The evidence points strongly to a decrease in the Poulkova Refractions, for this place, if the standard systems above enumerated are to be reconciled with the observations made here. The differences increase proportionally, as Declinations, below the limits above, are used for the deviations of Latitude.”

“As explained in full detail, earlier, the observations have been reduced with such of the Southern Piazzzi stars as Fundamental, as are included in AUWERS'S corrected *B. J.* and 303, the system of the last-named having been adopted. In extending the Declinations beyond the limits of the Fundamental stars, comparisons with AUWERS, NEWCOMB, and BOSS have been made, for the determination of the corrections to the Poulkova Refractions, employed throughout.”

The observations are grouped in two tabular exhibits. In the first there are given for each star the separate determinations of Right Ascension and Declination, and the correction to the latter derived by diminishing the Poulkova Refractions. The second exhibit is in the ordinary catalogue form, the refraction correction just mentioned having been applied to each Declination.

#### REFERENCE-STARS FOR *EROS*.

These observations were made to assist in determining the parallax of *Eros* at its opposition in 1900. There were 677 stars in all, which were observed on fifty-four nights, two de-

terminations of the place of each star being made. The probable error of the final place of a star was  $\pm 0''.20$  in each co-ordinate.

#### MISCELLANEOUS OBSERVATIONS.

These embrace determinations of the places of forty-nine comparison-stars, for other observers or orbit-computers, of twenty proper-motion stars for Professor J. G. PORTER, of *Eros*, of *Nova Persei*, and of comets *b* 1897 and *c* 1898.

#### THE INSTRUMENTAL CONSTANTS.

Under this caption are given the values of the constants during the four years and a half covered by the observations in the volume. The twenty-eight determinations of the flexure correction vary from  $-0''.31$  to  $+0''.21$ , the mean of all being only  $-0''.045$ . The nadir-readings seem to depend a little upon variations of temperature. The changes of collimation are very small, and its average value is close to zero. The total range of the azimuth-error was  $0^s.6$ , and it varied somewhat irregularly. The level-error changed in general slowly and smoothly, having an average value of about  $0^s.5$ .

Professor TUCKER received assistance from time to time in reading the circle-microscopes, and in reducing the observations, from Messrs. AITKEN, CODDINGTON, CRAWFORD, CURTISS, DALL, PALMER, and STEBBINS, the work of each of whom is particularly described. It appears that, had he received no aid, he would have made and reduced about 2,500 observations a year.

One closes this volume of the *Lick Observatory Publications* with a high admiration for the energy, precision, and painstaking of the observer, and with a feeling of satisfaction that he uses an instrument so perfect in a location so favorable. The results speak for themselves, and are a distinct credit to American astronomy.

HERBERT A. HOWE.

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